National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Fort Collins, Colorado

Invasive Species Early Detection Monitoring Protocol for Klamath Network Parks

Klamath Network

Natural Resource Report NPS/KLMN/NRR—2010/227

ON THE COVER
Scotch broom (*Cytisus scoparius*) growing in ponderosa pine woodland in the Klamath Region.
Photograph by: Dennis Odion

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1.0 Background and Objectives

1.1 Rationale for Early Detection Monitoring of Invasive Plants

Non-native, invasive species are a paramount concern in virtually all natural areas and, not surprisingly, ranked as the top vital sign for monitoring within the Klamath Network. Impacts of invasives threaten the core goals of the National Park Service. Invasive species are second only to habitat loss as a threat to native biodiversity (Wilcove et al. 1998). Impacts from invasives that can severely degrade native ecosystems include the replacement of native vegetation (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure (Mack and D'Antonio 1998), alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), changes in water availability (D'Antonio and Mahall 1991), and alteration of disturbance regimes (Mack and D'Antonio 1998). Invasive species having these effects are ecosystem transformers. Invasive species capable of transforming ecosystems are the focus of this protocol.

Invasive plant species also negatively affect park resources in non-ecological ways that are a threat to National Park Service goals. Visitor enjoyment can be impaired in several ways, including altering landscapes and historic viewsheds, encroaching upon trails, and acting as a form of visual pollution. Invasives may hinder trail work by diverting resources or increasing trail maintenance needs.

Despite much appreciation for the potential negative effects of invasives, our understanding of their full consequences and manifestations is far from complete. Monitoring can play a key role in filling this void and help with managing to limit the consequences of invasives.

Although a variety of invasive plants, animals, and pathogens are of concern in the Klamath Network, invasive plants are the most pervasive problem. Therefore, the Network's monitoring under this protocol will concentrate on early detection of invasive plants. Early detection is cost-effective, in that it can identify populations for removal, control, or eradication before they become entrenched within a park (OTA 1993, Myers et al. 2000, Harris et al. 2001, Rejmanek and Pitcairn 2002, Timmins and Braithwaite 2002). In addition to saving money, early detection and rapid response efforts minimize ecological damage caused by control efforts, which may become futile if not done early in the invasion process (Rejmanek and Pitcairn 2002). Given the limited resources of the Network, early detection is an especially pragmatic approach. A more complete discussion of the merits of early detection is presented in Appendix A and in the USGS/NPS Early Detection of Invasive Species Handbook (http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm).

This protocol will focus on species that are not yet well established and are along roads and trails. Part of the reason this protocol focuses on early detection along the roads and trails is because the vegetation monitoring protocol the Network is developing proposes to broadly sample invasive plants, both spatially and taxonomically. The invasive species early detection protocol described here and the vegetation protocol complement one another to provide a broader picture of invasive species' status and trends than either would alone.

1.2 Link to National Strategy

Early detection of invasive species is a nation-wide issue. Many parks and networks are working on early detection protocols collaboratively and individually. In 2002, the National Research Council thoroughly reviewed the state of knowledge on invasive species invasions (non-indigenous species). Their key recommendations for furthering knowledge and preventing invasions include the following:

- "…Careful recording of the circumstances of arrival, persistence, and invasion of non-indigenous species in the United States would substantially improve prediction and risk assessment."
- "Information on the structure and composition of natural ecosystems in North America (and the disturbance regimes within them) should be reinterpreted by the scientific community to analyze these ecosystems' vulnerability to biotic invasion. Attention should be paid to identifying groups of native species that could be vulnerable or could facilitate the establishment of non-indigenous species."
- "A central repository of information relevant to immigrant species would accelerate efforts to strengthen the scientific basis of predicting invasion. Information collected by federal, state, and international agencies; academic researchers; and others should be brought together in a single information facility or service so that it can be evaluated collectively, to permit the construction of needed datasets and the design of appropriate experiments, and to document the circumstances surrounding invasions."

Through the implementation of this and other invasive species monitoring protocols, the National Park Service will be building on these important recommendations as a contribution to the greater body of knowledge regarding the threat of invasive species in the United States.

This protocol will also serve to meet invasive species goals that were mandated by the National Park Service as part of the Natural Resource Challenge that established 32 Inventory & Monitoring (I&M) networks across the United States (National Parks Omnibus Management Act of 1998 [P.I. 105-391]). In 2002, the NPS I&M program held a workshop to recommend guidelines and tools for developing protocols for inventory and monitoring of invasive plants. One of the four adopted goals is to "prevent and detect new alien plant invasions, and eradicate new invasives" (Hiebert 2002, Benjamin and Hiebert 2004). This protocol meets the goal established in 2002 and follows standards that have been recently developed through the USGS-NPS Early Detection of Invasive Plants Handbook (http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm).

The NPS Invasive Species Action Plan (NPS 2006b) includes specific, recommended actions ranging from leadership and coordination to restoration. This protocol meets or helps to meet the guidelines and suggestions of the following actions from the plan:

- 1A.2: Develop NPS capability at a regional or multi-park level.
- 1B.1: Expand partnerships to maximize results.
- 1C.3: Rank invasive species for each park unit.
- 3A.3: Contribute to the development of national standards for all aspects of invasive species management.
- 6A.2: Improve the quality of the invasive species data in the NPSpecies database.

The protocol is linked to the action plan by being Network-wide, partnering with parks, ranking invasives by park, and providing knowledge on the management and distribution of invasives.

1.3 Monitoring History

Managing invasive species has been an important component of resource protection in the parks in the Network for decades. There are various informal monitoring efforts associated with management of invasives, but no formal early detection program. There are maps of invasive species occurrences that have been produced, known locations of management treatments, and substantial knowledge among resource staff. There are data from fire management Fire Monitoring Handbook (FMH) plots in burns, fuelbreaks, etc., and other vegetation sampling that has documented invasive species. At Lava Beds, Youth Conservation Corps volunteers produce a database of invasive species locations annually from surveys throughout much of the park. Nonetheless, there is no standardized, repeatable monitoring being done that can rigorously assess the status and trends in invasive plants in the Network, nor are existing efforts focused on early detection.

The Network undertook an inventory of invasive plant species in five of the six parks during Fiscal Year 2003 to build a base of knowledge about invasive species distribution and abundance in landscapes of the parks. Three primary survey methods, singly or in combination, were employed: (1) site profile surveys of known disturbed areas, (2) targeted mapping of invasive species, and (3) establishment of quantitative belt plots for non-native vegetation. Belt plots were installed on randomly selected linear road and trail segments, and encompassed different elevations and vegetation types in each park. Complete methods and results are described in Sarr et al. (2004).

Across the Network, the most striking pattern observed in the inventory was that mean richness of non-native species in the 1 ha belt subplots declined sharply from low elevations of Whiskeytown to the higher elevations at Lassen Volcanic (Figure 1). At low elevations, richness declined with belt distance from the road or trail, but this pattern was not evident at mid and high elevation sites, at least within the 100 m distance selected for the belt transect.

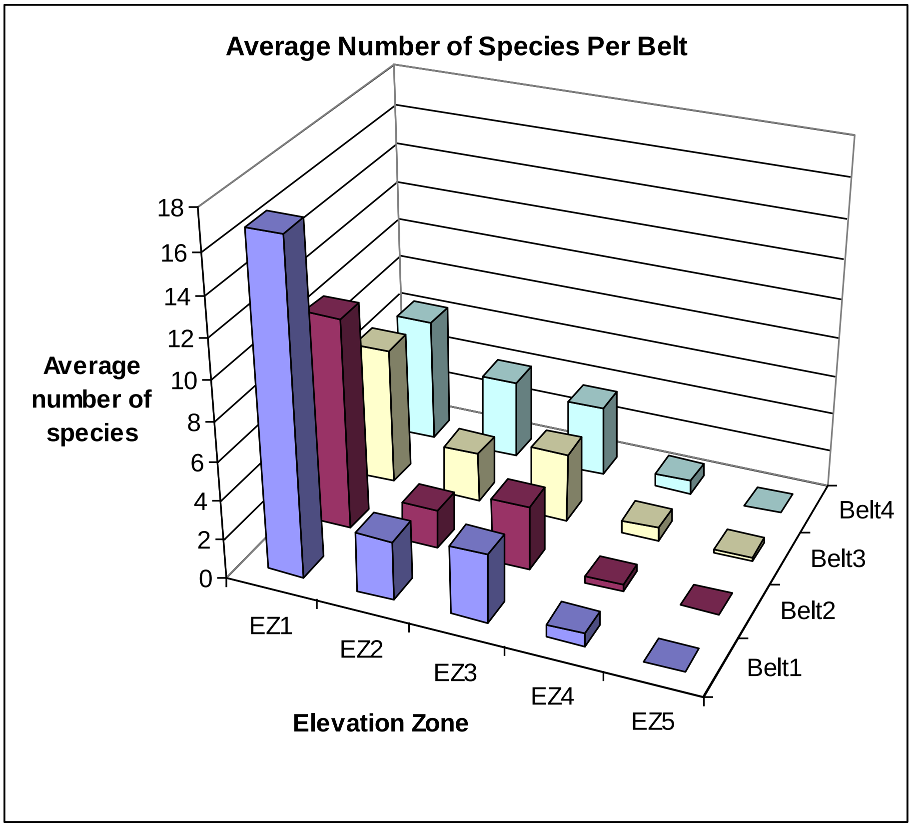

Figure 1. Average non-native species richness in 24 (1 ha) quantitative belt plots grouped by elevation zone (EZ1 = 0-500 m, EZ2 = 500-1000 m, EZ3 = 1000-1500 m, EZ4 = 1500-2000 m, EZ 5 = 2000-2500 m) and belt distance from a road or trail (Belt 1 = 0-25 m, Belt 2 = 25-50 m, Belt 3 = 50-75 m, Belt 4 = 75-100 m).

The monitoring history in the Network also includes a pilot study conducted to test this invasive species early detection protocol. The pilot study was conducted in fall 2007. Two researchers spent 5 weeks sampling in Redwood National and State Parks. Findings from the pilot study have been incorporated as improvements to the original sampling design as described in the relevant sections of this protocol. A report on the pilot study and its findings is presented in Appendix B.

1.4 Network Invasive Species Early Detection Conceptual Models

In the development of this protocol, the Network has considered a number of interacting factors relating to the invasion process and monitoring. These are summarized conceptually in Figure 2. Park management, the susceptibility of park landscapes to invasion, and species environmental tolerances directly affect the invasion process.

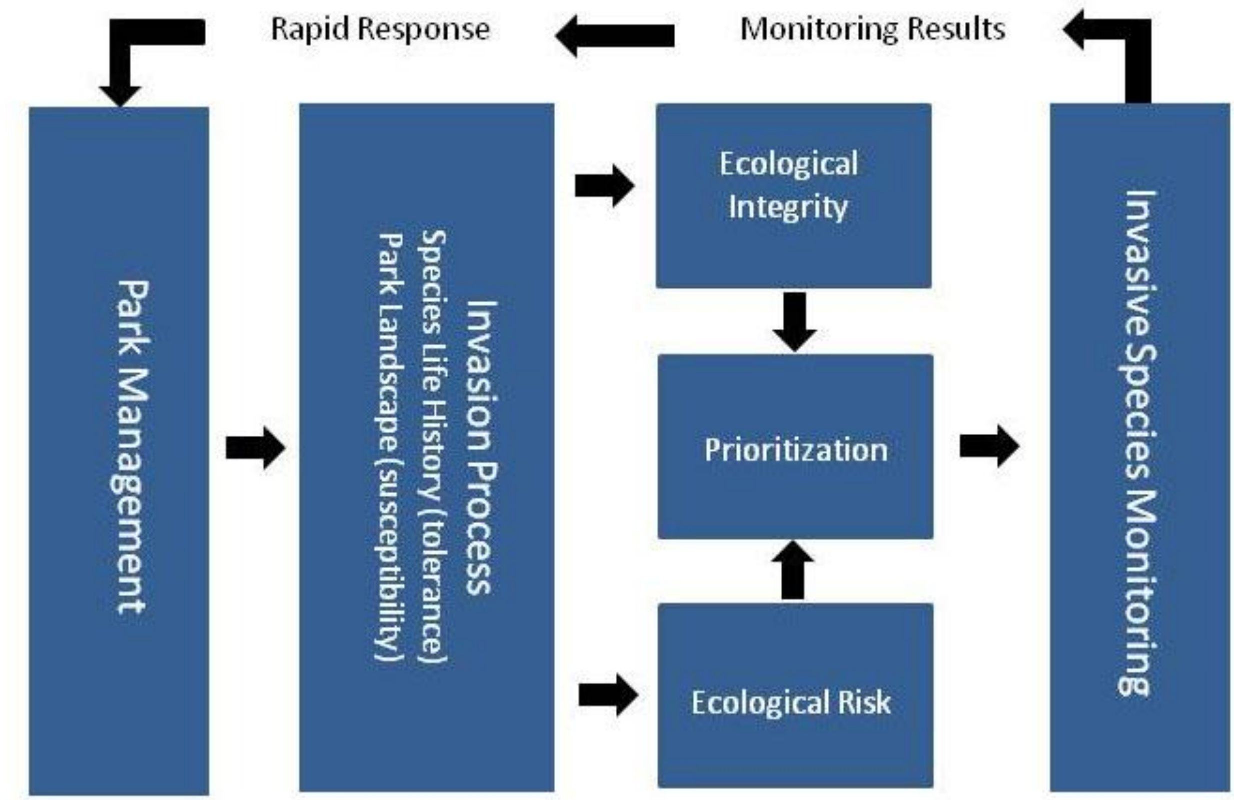

Figure 2. Conceptual model of the Klamath Network's invasive species early detection monitoring protocol. Park management and invasive control efforts affect the invasion process. This process places differential ecological risks across the park landscape, affecting ecological integrity. These effects determine the prioritization of species and locations to sample in the invasive species monitoring protocol. The results of this monitoring feed directly into rapid response, a component of park management of invasives.

The invasion process in turn affects the ecological integrity of parks and the risk of degradation. These are key factors in prioritizing which species to monitor. Also key is feedback from monitoring to support rapid response by park managers. We explore these interrelated aspects of the invasion process further with conceptual modeling.

1.4.1 Susceptibility of Park Landscapes

Past inventories and park-wide species lists strongly suggest that vulnerability to invasive plants varies considerably among parks in the Klamath Network. Although the number of non-native species present generally increases with park area, many more invasive species are present at parks with lower elevations (Figure 3). Thus, at both of the parks with the lowest elevations, Whiskeytown and Redwood, far more invasives may be found in a given-sized area than the higher elevation parks. Non-climate factors promoting invasion at Whiskeytown appear to be mechanical and soil disturbances associated with fuelbreak construction and maintenance, vegetation mastication, prescribed burning (particularly where mastication slash resides), wildfires, and vegetation management under a powerline corridor traversing the park. Redwood has a major highway running through it, high levels of visitor use, and past anthropogenic and natural disturbances, as well as coastal processes that may be linked to invasions. The shrubsteppe ecosystems at Lava Beds are also vulnerable to invasives, due to relatively open vegetation and an abundant source of invasive propagules from surrounding agricultural lands and various disturbances, such a fire. Most of Crater Lake and Lassen Volcanic National Parks is high enough in elevation that the numbers of invasive species are comparatively low for their sizes.

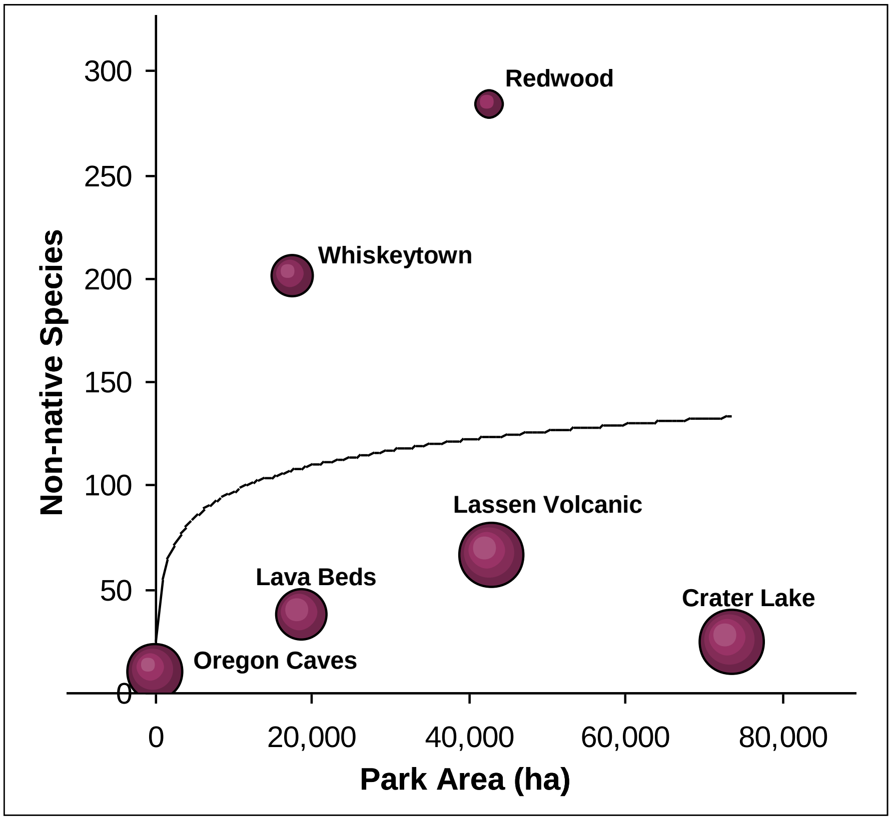

Figure 3. Non-native species richness as a function of park area in National Park system units in the Klamath Network. A logarithmic line is provided to illustrate the expected species / area relationship across park sizes; bubble size is proportional to mean park elevation. The lower elevation parks have more non-native species than expected for their size, whereas higher elevation parks have fewer recorded species.

Based on these general patterns of invasive plant species richness, the lower elevation parks will have a much wider range of species of potential concern and efforts there could easily outstrip the resources available. Prioritization of which species to monitor, therefore, will be essential to assuring that we can allocate monitoring efforts to locate the most pressing concerns in these parks.

1.4.2 Species Tolerances

As an initial step in predicting the abiotic conditions favoring species invasion, we have developed a semi-quantitative conceptual model to link species' physiological tolerances with potentially invasible park habitats. To develop this model, we undertook the following research and analysis of the species that were included in the prioritization described in Appendix A.

For each species, a number of sources were checked for habitat preferences and elevation limits. Sources included the Jepson Manual (Hickman 1993, D'Antonio et al. 2004) for elevations and habitat preferences. In addition, numerous online sources such as the California Invasive Plant Council's web page (http://www.cal-ipc.org/) and expert opinion of park resource managers as described in SOP #1: Invasive Species Prioritization. The following attributes were coded for each species to create a species/attribute matrix.

A. Cold Tolerance:
    1 = Intolerant. Occurs only at or near sea level.
    2 = Somewhat tolerant. Occurs below 1,000 m elevation.
    3 = Fairly tolerant. Can occur from 1,000 – 2,000 m elevation.
    4 = Tolerant. Occurs above 2,000 m.
B. Shade Tolerance:
    1 = Intolerant. A light-demanding species, found almost exclusively in full sun.
    2 = Somewhat intolerant. Can handle some shade.
    3 = Somewhat tolerant. Can grow in understory of open forest or shrubland.
    4 = Very tolerant. Can grow in the understory of a closed forest or shrubland.
C. Moisture Requirements or Drought Tolerance:
    1 = Aquatic.
    2 = High moisture requirement, not drought tolerant.
    3 = Moderate moisture requirement, somewhat drought tolerant.
    4 = Low moisture requirement, drought tolerant, or annual species.
D. Soil Nutrients:
    1 = Intolerant of low nutrient soils or substrata.
    2 = Fairly tolerant of low nutrient soils or substrata.
    3 = Tolerant of low nutrient soils or substrata.
E. Salt Tolerance:
    1 = Not known to occur on salt affected substrata.
    2 = Can grow on salt-affected substrata.

Species were classified into three groups using cluster analysis in the software package PC Ord. The species were then ordinated by their tolerance values using Principal Components Analysis in PC Ord. The result is a diagram visually illustrating patterns of species' tolerances. In the diagram, species with similar attributes cluster together in ordination space (Figure 4). Tolerances variables are overlaid as vectors to create a biplot.

The ordination in Figure 4 shows that the most variation among species (43%) is explained along a primary environmental gradient (Axis 1) relating to cold tolerance. This reflects effects of elevation and/or continentality at one extreme and mild and humid coastal conditions at the other. The second gradient, Axis 2, explains 31% of the variance. Axis 2 is closely related to a combination of drought tolerance and shade intolerance on one extreme, and shade tolerance and drought intolerance on the other. Drought tolerance is positively correlated with tolerance of low soil nutrients.

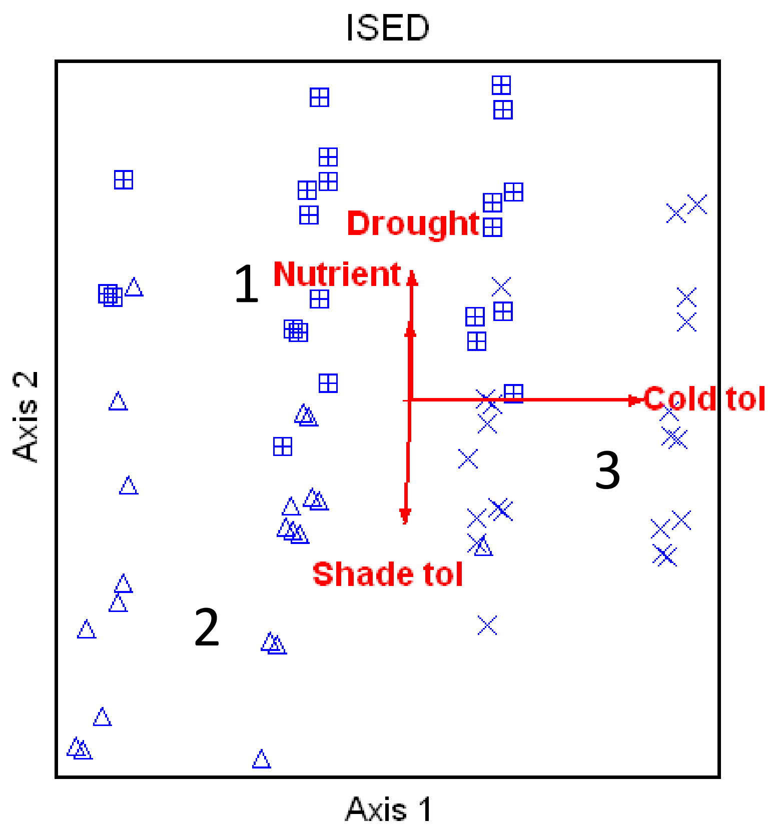

Figure 4. Ordination biplot of invasive species in the Klamath Network based on physiological tolerances. The first axis explains 43% of the variation in tolerance values among 166 species, while the second axis explains 31%. Some labels represent the locations of more than one species in the ordination space. Group 1 are squares, Group 2 are triangles, and group 3 are X's.

Cluster analysis identified three general groups of species with distinctive combinations of drought/nutrient, shade and cold tolerance. Group 1 consists of invasives species that are tolerant of drought and low soil nutrients but intolerant of deep shade or cold temperature extremes. Such species are capable of primarily invading low elevation, open environments. Of the 166 total species in the ordination, group 1 contains 55. Eighteen of these species were ranked as early detection priorities (SOP #1: Invasive Species Prioritization). Some were ranked in more than one park, leading to a total of 27 times that a species from group 1 was prioritized for monitoring among the six park lists. Of these, one species, Scotch broom (*Cytisus scoparius*), was prioritized in four parks and another, cheatgrass (*Bromus tectorum*) was prioritized in three parks.

Group two consists of species that are relatively shade tolerant and drought intolerant. Consistent with general observations that there are fewer shade tolerant invasives in general, this group has fewer species (48) and occurrences of species prioritized for monitoring among the six park-specific lists (22). Moreover, only one of these species, dyer's woad (*Isatis tinctoria*) was prioritized for monitoring in more than one park, and this species may be among the least shade tolerant in this group. Although there are fewer species in this group, there is much habitat in the Klamath Network where species in this group can invade, for example, most of Redwood and Oregon Caves. Moreover, the group includes species that are shade tolerant enough to invade the understory of intact redwood forests, for example, holly (*Ilex aquifolium*) and Robert's geranium (*Geranium robertianum*).

Given that high elevation environments are generally the least invaded in the Network, it is surprising that group 3, characterized by moderate cold tolerance, contains the most species (69) and the greatest number of total occurrences of species prioritized for monitoring among park lists (52). In group 3, species are not only cold tolerant, but they are also able to tolerate drought and shade, as long at these are not extreme. Thus, group 3 species are characterized by particularly broad ecological amplitudes. They are species with classic ruderal characteristics. Group 3 contains Canada thistle (*Cirsium canadensis*), yellow starthistle (*Centaurea solstitialis*), knapweed (*Centaurea maculata*), and dalmation toadflax (*Linaria genistifolia*), all ranked among top early detection invasives in four or five parks (SOP #1: Invasive Species Prioritization). Members of group 3 should be considered as potential invaders of middle, and in some cases, upper elevations in the Klamath parks.

1.4.3 Landscape Susceptibility to Plant Invasion

As we have seen, it will be important to detect invasive species in all habitats throughout the Network. However, resources are too limited to monitor everywhere. Most invasive species cannot tolerate shady environments. In addition, the Klamath Network's invasive species inventory found a strong association between invasives and roads in the five Network parks that were sampled. Moreover, in the pilot study for this protocol, road and trail density were the most important predictors of the distribution of the most commonly encountered early detection species, Klamath weed (*Hypericum perforatum*). This is an invasion profile that likely fits many, if not most, invasive species. There are numerous studies of vegetation that have documented a very strong local association between roads and trails and invasive species (Trombulak and Frissell 2000, Douglas and Matlack 2006). The occurrence of invasive plants has been found to predictably decline with distance from roads and trails (Reed et al. 1996, Greenberg et al. 1997, Parendes and Jones 2000, Silveri et al. 2001, Watkins et al. 2003). The increased abundance of invasives alongside roads has been related to road surface materials (Greenberg et al. 1997, Silveri et al. 2001), light (Parendes and Jones 2000), and higher frequency of disturbance (e.g., Parendes and Jones 2000). Gelbard and Belknap (2003) found much greater numbers of invasives along paved road verges than on 4-wheel drive tracks. Other transportation, utility, and riparian corridors, along with fuelbreaks (Merriam et al. 2006), have many of the same features as roads (disturbance and propagule pressure), making them also suited to invasion. With a conceptual linkage between transportation and utility corridors and invasives, we have identified these corridors as the locations for our invasive species early detection monitoring.

As data are collected, we can refine our conceptual understanding of the relationships between invasive species and the environments in which they are found using spatial modeling (SOP #10: Reporting and Analyses of Data). Figure 5 shows one type of output from this modeling from data collected at Redwood. Models will provide a conceptual basis for predicting beyond the current known range of invasives to new areas in the parks. This modeling will also use data from the vegetation monitoring protocol so that predictive modeling is not as strictly limited to road and trailside environments.

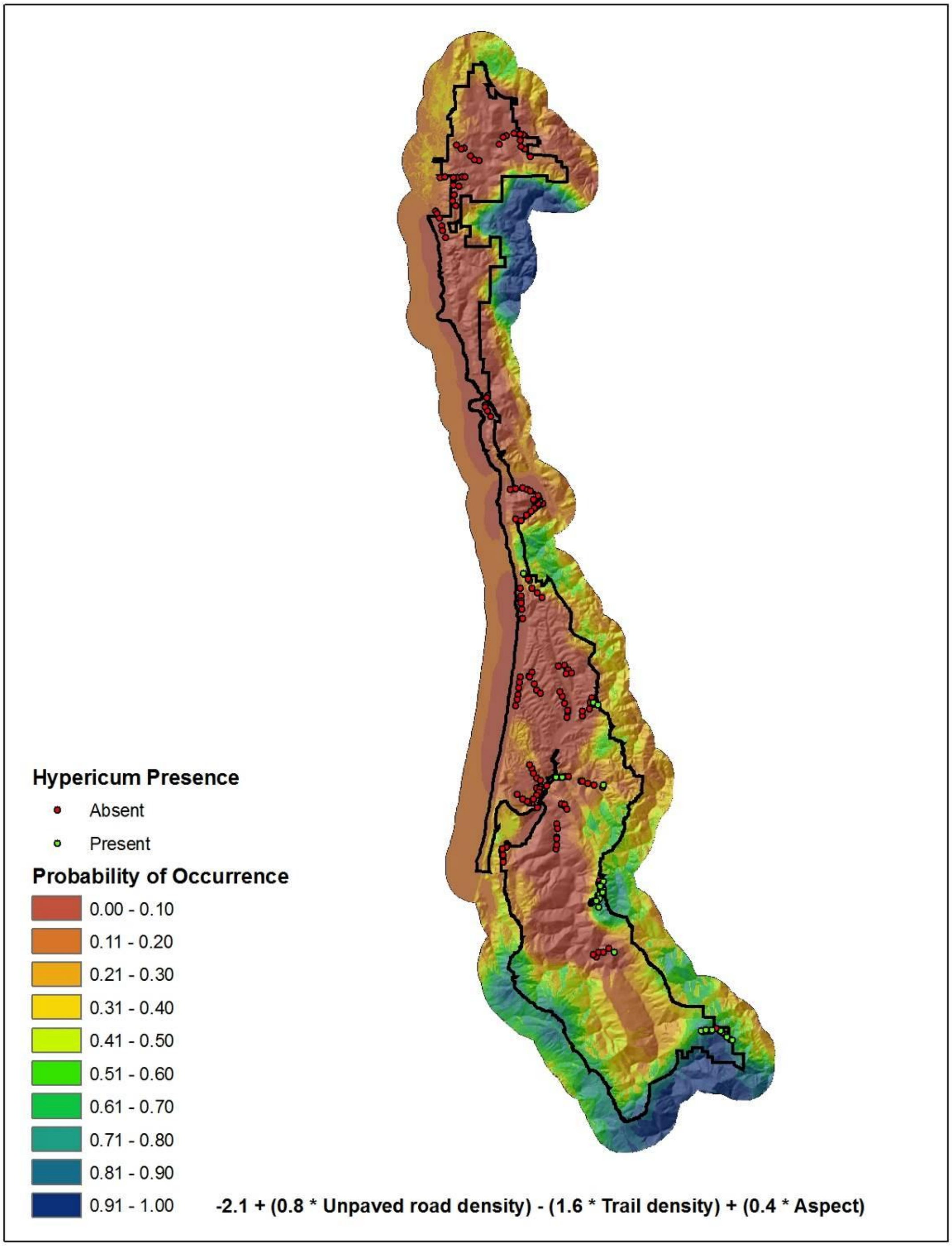

Figure 5. Interpolated surface showing the probability of occurrence of Klamath weed (*Hypericum perforatum*), at Redwood National Park. Data used in the modeling were collected during the pilot study, described in Appendix B.

1.4.3 Ecological Integrity and Risk and Species Prioritization

Ecological integrity is based on the level to which an ecosystem has been degraded as a result of human activities. We use this concept to modify our prioritization of invasives for early detection. The risk of degradation due to a non-native species invasion is proportional to the ecological integrity of the habitat invaded. Some species, which may be prioritized as well established from a park-wide perspective, and thus not monitored, may be important to consider from an early detection standpoint in remote parts of a park with high ecological integrity. Conversely, where ecological integrity is very low, it may not make sense to monitor invasives at all. Thus, it is difficult to apply a uniform species prioritization across heterogeneous landscapes. The general relationship between ecological integrity and the ranking of species via prioritization is shown conceptually in Figure 6. We incorporate the concepts shown in Figure 4 in this protocol by including equilibrium species in the monitoring where they are currently not found, as determined by park resource specialists (SOP #1: Invasive Species Prioritization).

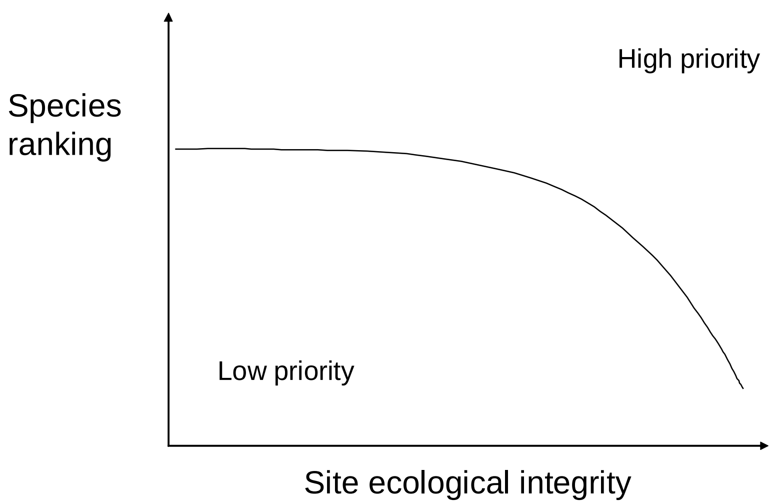

Figure 6. Conceptual model of how invasive species priorities may change as a function of the ecological integrity of sites where they are found.

1.4.4 Rapid Response

A key element of early detection monitoring that is recognized in the Network's overall concept of the role of invasive species monitoring is rapid response. This is the link between monitoring and management (Figure 2). This protocol recognizes the need to link monitoring and rapid response, and we have designed a reporting scheme using briefings to quickly communicate the most urgent findings to park managers (SOP #10: Reporting and Analyses of Data).

Currently, managers in Klamath Network parks attempt to respond to invasive species threats to the extent possible given existing resources. Three of the California parks, Lassen Volcanic, Redwood, and Whiskeytown, get Exotic Plant Management Team (EPMT) support, which can help with rapid response needs. These teams will be on the distribution list for the different reports produced by this protocol. However, the EPMT crews in California are stretched thin trying to provide for numerous parks, so their ability to provide rapid response is limited. Ultimately, an early detection monitoring protocol, however well designed, will fail to support park management goals unless specific arrangements are made to fully integrate the scientific findings with management actions on the ground. A complete vision of early detection and rapid response will require that additional fiscal and staffing resources are made available to support rapid response. Fortunately, there is regional support for more network level collaboration on exotic plant control within the parks. Park staff within the Network are very supportive of this idea. While parks would still maintain their own exotic plant control programs, a network approach would offer the Klamath parks the opportunity to collaborate more on control techniques, exchange expertise, coordinate on weed data management, maximize training opportunities, and create a flexible approach to exotic plant control over the season. All of these, in concert with the Network's monitoring efforts, would facilitate rapid response to early detection of invasives. The network of parks is in the early stages of conceiving such an integrated program; we will be exploring ways to make it a reality in the next few years.

1.5 Relationship to Other Vital Signs Monitoring by the Network

Invasive species were part of the reason vegetation, land cover, whitebark pine, cave entrance, aquatic communities, and intertidal communities were selected as vital signs. Useful and complementary information on status and trends of invasive species will come from monitoring these other vital signs, and this helped us refine the invasive species monitored in this protocol. For example, as mentioned above, the vegetation protocol will monitor the status and trends of invasives present in broad vegetation types and will help detect new occurrences. Since the sampling design for the vegetation protocol is probabilistic, and representative of all park habitats (Sarr et al. 2007), the data may be useful for modeling of invasive species habitat relations. Secondly, monitoring of blister rust should be adequate to determine trends in the invasion of this non-native pathogen in whitebark pine. Third, severe infestations or vegetation change to non-native species (e.g., type conversion to cheatgrass) may be monitored under the land cover protocol. Lastly, aquatic community and marine intertidal monitoring will add different ecosystem types in which invasive species will be tracked and potentially managed should they become problematic.

1.6 Protocol Objectives

1.6.1 Management Objectives

In considering the invasive species protocol, the Network also had to recognize that the vital signs scoping and ranking process did not specifically identify early detection among its broader monitoring questions and goals. The Network therefore met with park resource staff who have been intimately involved in managing invasive species. The purpose of this was to weigh early detection along with other non-native species monitoring objectives on a park-by-park basis. Some parks, such as Lava Beds, have already been conducting their own early detection monitoring or feel that early detection is handled very well by *de facto* monitoring by resource staff. It is important to recognize that this is not the same as a peer-reviewed, repeatable, science-based monitoring program with regular data analysis and reporting requirements, as developed under the NPS Inventory and Monitoring Program. Other parks have a need for monitoring that is broader than early detection alone. Staff from large parks ranked the invasive species management needs in their parks (Table 1), making no assumptions about the degree to which these needs can and should be met by network funding.

Table 1. Park ranking of needed components of an invasive species monitoring program for management in each large park. Components could be integrated to varying degrees with the Klamath Network's monitoring. Priorities are: 1= high, 2 = medium, 3 = low, 0 = not needed.

Program Item Needed	Crater Lake	Lava Beds	Lassen Volcanic	Redwood	Whiskeytown
Baseline mapping/inventory of invasive plants in park	0	3	2	3	1
Invasive Species Early Detection (ISED)	2	3	1	1	1
Status and trends monitoring	1	0	1	2	1-2
Technical Assistance					
GIS/Data management	3	3	1	2	2
Botanical expertise	3	1	0	0	2
Control methods	1	1	0	0	0
Prioritization (for ISED, not existing species)	2	2	3	0	0
Outreach and coordination of volunteers, staff, etc.	1	1	2	2	2
Curatorial assistance	3	1	3	0	2
Control	1	0	1	1	1

Based on these rankings, the Network developed the following *management* objectives:

1. Provide early detection of invasive plant species to assist managers in controlling or preventing new populations of high priority invasives from establishing.
2. Provide some outreach and education to help increase the potential for invasives to be detected in parks. Examples include illustrated invasive species identification guides to be produced and made available to support and inform park-based staff, visitors, and volunteer programs.
3. Provide taxonomic expertise to allow rapid identification and associated research to determine possible control methods for new species. This is most important for Lava Beds.

1.6.2 Monitoring Objectives

With other invasive species needs covered by other protocols, the Network recognized that the monitoring objectives for its ISED protocol could emphasize vascular plants.

1. Detect populations of selected invasive plants by sampling along roads, trails, and powerline corridors, and in campgrounds, where introduction is most likely.
2. Provide the early detection information to park management on a timely basis to allow effective management responses.
3. Develop and maintain a list of priority invasive plant species with greatest potential for spread and impact to park resources for monitoring in each park.
4. Adapt spatial sampling as knowledge improves through monitoring.
5. Use monitoring data collected from this protocol and the vegetation protocol to estimate possible trends and develop and refine models of invasive species habitat requirements and of the most susceptible habitats (both along roads and trails as well as elsewhere).

1.6.3 Sampling Objectives

1. Every 2 years, sample road and trail segments (generally 3 km) in each park, as many as possible, using a probabilistic sampling design to maximize detection of priority species.

2. Every 2 years, sample plots in infested and uninfested areas in an unbiased manner to provide data for species habitat modeling.

1.7 Protocol Standards

The Klamath Network ISED Protocol will be evaluated by the following broad management and scientific standards:

1) The protocol provides accurate, timely, and actionable information for invasive plant management in parks of the Klamath Network.

2) The protocol provides quantitative information about invasive plant species that supports spatial and temporal models of invasion risk in the Klamath Network parks.

3) The protocol contributes to a broader scientific understanding of invasive species ecology and management in the Klamath Network parks and in invasive species science in general.

The performance of the protocol in meeting these standards will be evaluated in Analysis and Synthesis Reports 1-3 (SOP #10: Reporting and Analysis of Data).

2.0 Sampling Design

2.1 Rationale for Selection of Species

Species prioritization was conducted on a park-by-park basis and the results are summarized in SOP #1: Invasive Species Prioritization. The full prioritization report is presented in Appendix A. Robert Klinger and Matt Brooks (USGS) undertook the Network's park-level prioritization process, with input from park and Network staff. Species prioritization was done differently among Klamath Network parks according to the information available. The prioritization was completed with existing quantitative data for Lava Beds and Whiskeytown, where the most data were available on invasive species' distribution and abundance. For other parks, expert opinion in concert with existing literature was used to prioritize species.

For each park, a list of invasive species present, with additional species that could invade based on the literature, was finalized. Then these species were classified into the invasion stage in which they are found in each park: colonization, spread, or equilibrium or not an invasive that transforms ecosystems. This was based on expert opinion of park staff, and invasiveness rankings by CAL-IPPC and other literature. Only species that were a consensus to be non-threats were excluded from the ranking. If there was any question, the species was included.

Colonization and spread species are the focus of early detection in this protocol. Depending on the park and species' ranking score, most or all of the colonization and spread species were selected as the priority species to monitor throughout a park (SOP #1: Invasive Species Prioritization). Equilibrium species whose locations will also be recorded in portions of the park with high ecological integrity are also listed in SOP #1.

Prior to the start of the sampling season, after the road and trail segments are selected for monitoring, the Crew Lead will consult with the Park Contact to discuss the segments and campgrounds that will be sampled that year. Those segments or campgrounds in which particular equilibrium species will also be will be identified if they have not already been. These roads and trails are currently defined for most parks based on elevation or wilderness areas (SOP #1: Invasive Species Prioritization).

The procedure for updating the prioritization lists and how the Network will research new invasive species threats to add to the lists for future re-prioritizations is also described in SOP #1: Invasive Plant Prioritization. With new invasions, control of existing invasions, changes in species' abundance, and new understanding of the threats particular species pose, prioritizations may need to be adjusted. This will be done in a comprehensive way every 5 years with the issuance of Analysis and Synthesis Reports (SOP #10: Reporting and Analyses of Data).

2.2 Rationale for Sampling Design

As described above in section 1.5, there is a strong association between invasive species and roads, trails, campgrounds, utility corridors, and fuelbreaks. In order to maximize efficiency in finding invasive species, these locations will be the target of monitoring efforts by the Network, except fuelbreaks, which are monitored under the auspices of fire management.

2.2.1 Sample Design

The spatial sampling design for each park is shown in Figure 7 and described in SOP #5: Field Survey Methods. The sampling frame will consist of roads and trails that are not closed for safety reasons. Powerline corridors that can be traversed and campgrounds (as part of the road network) will be included in parks where applicable.

The road, trail, and powerline network will be broken into 3 km target segments. Figure 8 shows an example from Lava Beds. A random sample of segments will be surveyed every 2 years as shown in Figure 9. The revisit frequency for any particular segment will vary from park to park and segment to segment. Since we are making park-wide inference, we will select a subset from all segments in each park at the beginning of the field season, rather than trying to revisit as many segments as possible or trying to include as many as possible that were not previously sampled.

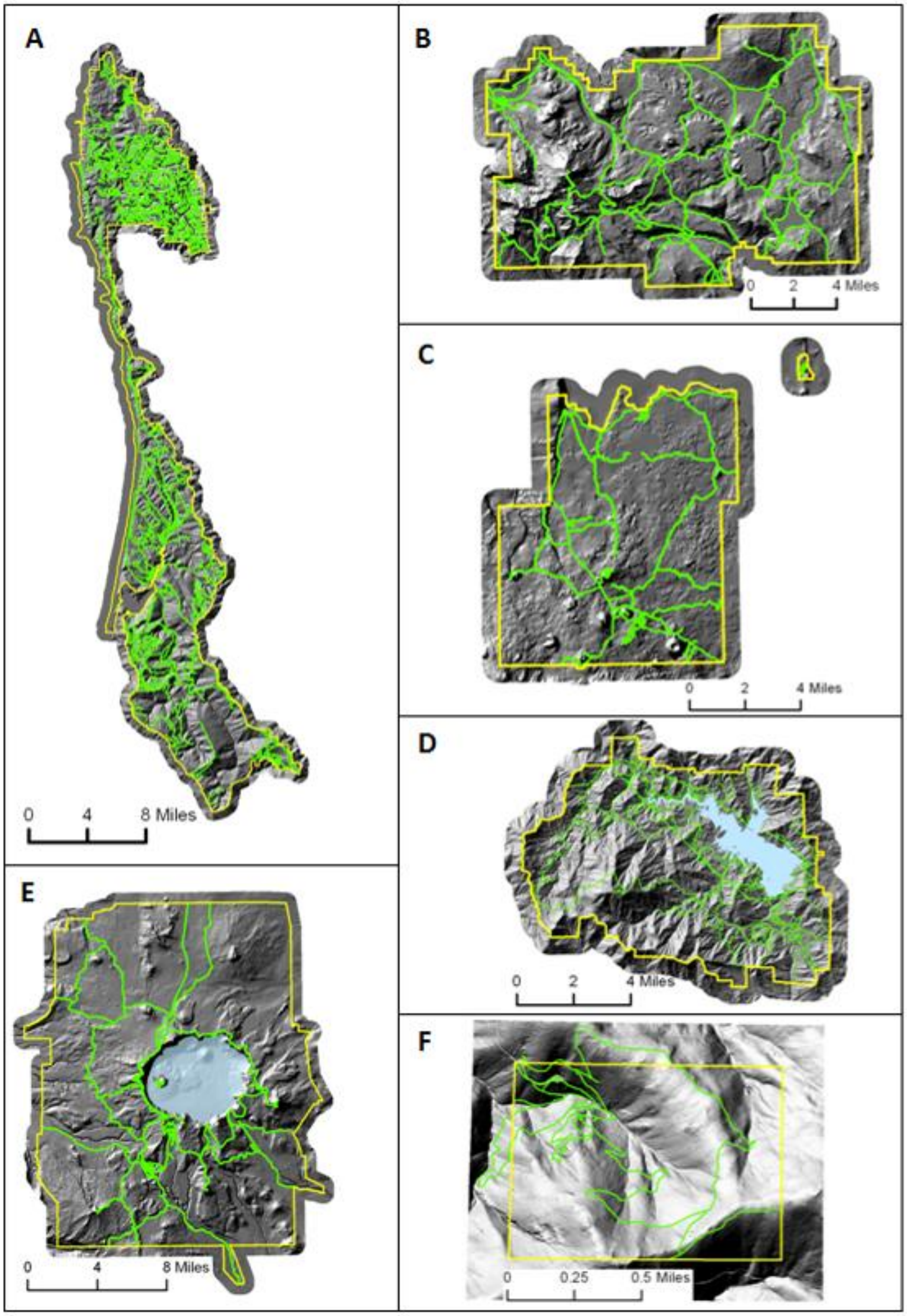

Figure 7. Sampling frames (green features) for (A) Redwood NSP, (B) Whiskeytown NRA, (C) Crater Lake NP, (D) Lassen Volcanic NP, (E) Lava Beds NM, and (F) Oregon Caves NM, include roads, trails, campgrounds, and powerline corridors. Park boundaries are outlined in yellow.

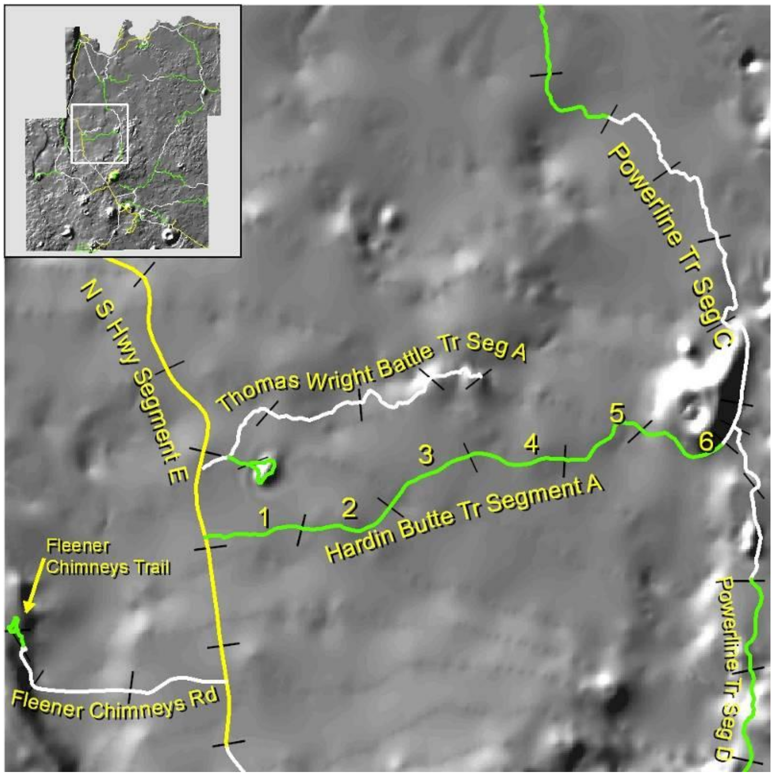

Figure 8. Close-up showing 3 km segments and 500 m subsegments (black lines). Hardin Butte Trail's 500 m subsegments at Lava Beds are labeled 1-6.

One end of a section of road, trail, or powerline corridor will serve as a starting point (Figure 9). Field crews will traverse the selected segment. A GPS coordinate of all prioritized species visible from the feature and an estimate of the infestation size will be recorded. Based on findings during the 2009 field season, we included in the sampling protocol instructions for mapping continuous populations and a maximum number of individual infestations (4) to be mapped per segment (SOP #5: Field Survey Methods).

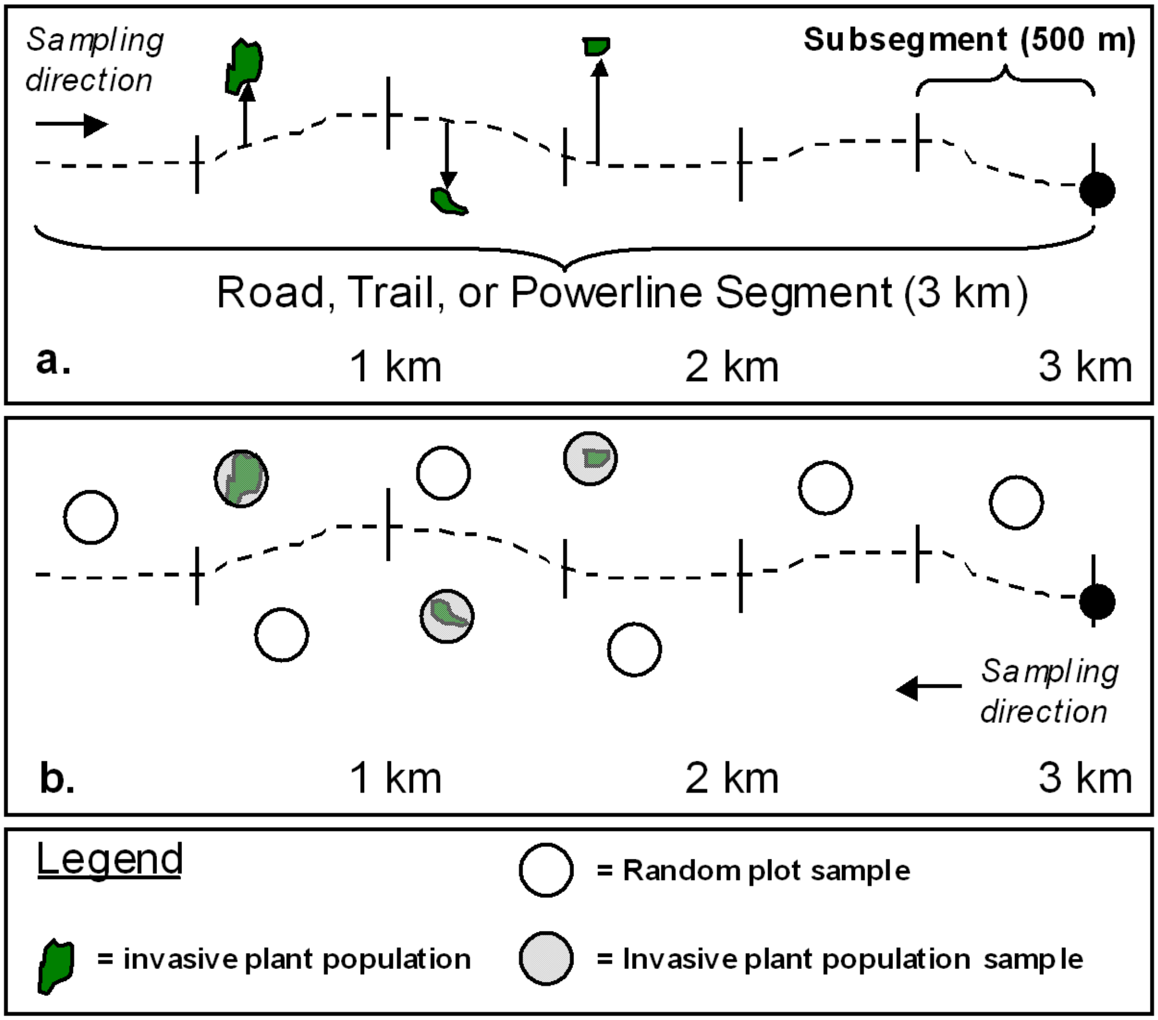

Figure 9 a and b. Illustration of the invasive species early detection response design to be completed at each randomly selected road, trail, or powerline segment in a park: a) location mapping and sampling of invasive plant populations; and b) plot sampling of random locations and the invasive plant populations located.

Crews will also place six 100 m^2 plots within each 3 km section of road, trail, or powerline corridor (one per 500 m). In these plots, they will sample the presence and abundance of invasive species and selected environmental variables (e.g., percent cover, soil disturbance, elevation, habitat type, etc., described in SOP #6: Data Collection and Entry). These samples will be supplemented by up to three opportunistic samples (if there are that many or more infestations found) for each invasive species detected along the road, trail, or powerline segment. These plots will be spread along the segment and selected at random when possible from multiple infestations, as described in SOP #5: Field Survey Methods. The methodology for locating and completing these plots was field tested in fall 2007 and summer 2009, and found to perform well. In general, two segments can be done in a day, but this depends on the number of infestations found.

2.3 Rationale for Selection of Parameters

The minimum parameters that will be measured for all prioritized species are presence/absence, location coordinates, and estimated infestation size. In addition, randomly selected infestations will be locations for plot sampling where numerous environmental variables (e.g., slope, aspect, tree cover, etc.) will be measured (SOP #5: Field Survey Methods). These same variables will be measured in randomly selected non-infestation plots. In general, this protocol emphasizes the quick collection of location and abundance data for invasive plants of greatest concern from an early detection perspective in the most likely places to find them. The data are likely to be immediately relevant to resource managers for planning control strategies, reporting on GPRA land health goals, and in some cases assessing effectiveness of control. The design is not optimized to assess the effectiveness of management treatments applied at small scales or to compare the effectiveness of control treatments. While this is an important goal for invasive species management, replicated experiments are the best approach to answering effectiveness questions. Nonetheless, the monitoring may provide information or abundance data to help address effectiveness questions, such as plot data that may serve as controls for comparison with experimental manipulations. In addition, questions such as whether management is keeping roadside infestations in check may be addressed using the monitoring data.

The design is also not suited to modeling distributions of invasives park-wide because inference cannot be extended from the roads, trails, and powerline corridors to the park as a whole. However, the habitat types and elevations of road and trail networks are quite representative of the parks as a whole (see analysis in the Network's monitoring plan [Sarr et al. 2007]). In addition, plot data up to 1 km away from roads and trails will be obtained from vegetation sampling under its separate protocol. The combined monitoring efforts should yield some important predictions about susceptibility of various park environments to invasive species that are found among the plots, except those that are still rare.

2.4 Site Selection

All trails in all parks are included in the sampling frame. Road segments that are unsafe to sample will not be included in the sampling frame. In addition, all drive-in campgrounds in each park will be sampled. Powerline corridors will be sampled.

2.5 Frequency and Timing of Sampling

Field sampling will occur every other year starting in 2009. Figure 10 shows the target times for field monitoring in each of the parks. Klamath Network-based crews will visit low elevations at Whiskeytown first, during early May. They will then visit Lava Beds and Redwood in May and June, and Oregon Caves and high elevations of Whiskeytown in June and into July. The two high elevation parks, Crater Lake and Lassen Volcanic, will be sampled from mid- to late July through early September. Unfinished work at Redwood can be completed any time during the second half of the field season. Actual times of each visit may need to be adjusted slightly in a given season based on logistical concerns, weather, or due to changes in the phenology of the target species. All such changes will be verified with the Park Contacts as early as feasible.

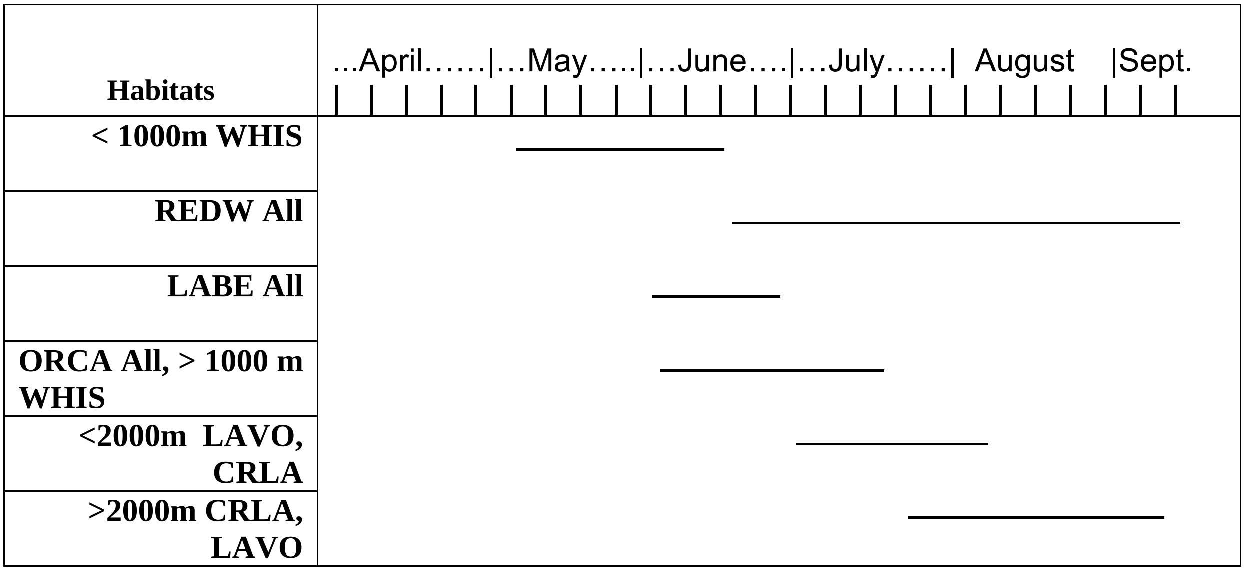

Figure 10. Timing for invasive species sampling in different elevation zones in different parks of the Klamath Network.

2.6 Sampling Effort in Parks

Sampling effort will be apportioned to allow a probabilistic sample of road, trail, or powerline segment in all five of the larger parks, with a complete census at ORCA (at least until the likely expansion occurs). Generally, the larger parks in the Network have between 160-500 miles of roads, trails, or powerline segments, with the exception of Redwood, which has nearly 900 km. Based on guidance in the Klamath Network Vital Signs Monitoring Plan (Sarr et al. 2007), we set a minimum sample size of 25 segments in each park. For Redwood, which has an exceptionally large road and trail network, we set the minimum at 35 segments (Table 2). This level of sampling should be feasible. Based on our pilot sampling work, we have determined that field crews can sample an average of two to three segments per day. Assuming a 6 month field season working on an 8 day on / 6 off schedule, 96 work days are available. With 2 weeks (8 days) of training, about 88 days are available for field work, travel, and data entry. Our conservative seasonal sampling target is, therefore, approximately 179 segments across the six parks (Table 2). Therefore, we should be able to exceed our statistical sampling standard and also provide some additional management-specific data in each sampling season.

2.7 Co-location of Other Vital Signs

Based on current planning, no other vital signs will be specifically co-located with invasive species early detection. There are no apparent opportunities for cost savings by co-locating the early detection monitoring described in this protocol with other vital signs monitoring. Other protocols will provide important information for the broader goal of invasive monitoring that will be used in concert with the invasive species early detection data. In particular, the vegetation monitoring protocol will help monitor invasive species that occur away from roads and trails.

Table 2. Total road, trail, and powerline distances (km) in the parks of the Network, and the sum and percent of the total for the Network. Also shown is the number of days out of 115 that each park's percent equates to, and then the number of days that will be allotted to each park after considering practical concerns.

Sample Unit/Effort		Crater Lake	Lava Beds	Lassen Volcanic	Oregon Caves	Redwood	Whiskeytown	Total
Roads	highway	111.9	50	55.2	1.1	128.4	53.5	400
	non-highway	35.6	21.1	14.8		517.1	168.9	686
Trails		234.9	63.9	282.9	8.7	220.2	84.7	1086
Powerline		0	0	0	0.3	7.3	34.7	42.3
Sum		382.3	135	517.3	9	873	341.8	2258.3
Minimum Sample Size		25	25	25	11	35	25	146
Allotted Sampling Weeks		4	4	4	1	5	4	22
Allotted Sampling Days		16	16	16	4	20	16	88
Projected Sample Size @ 2 segments/ Day		32	32	32	11	40	32	179

3.0 Field Methods

3.1 Field Season Preparation and Equipment Setup

Preparations for field work must begin several weeks before the season. Details for the preseason preparation are included in SOP #2: Field Work Preparation, while details on observer training are provided in SOP #3: Observer Training. In general, it is the Crew Lead’s responsibility to work with the Park Contacts to set up permits and to ensure availability of housing, keys, vehicles, radios, and computers when applicable. Sampling trips by Network crews will be scheduled and organized by the Crew Lead prior to the start of each field season. It is the Crew Lead’s responsibility to create a detailed work plan for each sampling trip prior to going into the field. The Crew Lead will ensure that the field crew is properly trained and has all the required gear and the most up-to-date field forms. It is also the Crew Lead’s responsibility to make certain all databases (handheld and desktop applications) and field equipment (e.g., laser rangefinders, GPS units, etc.) are calibrated and properly set up prior to heading into the field (SOP #4: Setting up the Electronic Field Equipment). The Crew Lead will work with the field crew to make sure it is clear where everyone is going, what is expected to be completed, and what the timelines are for when the work should be finished.

Prior to working in the field, each member of the field crew must review the job hazard assessment for this project and the entire protocol. With the Crew Lead, observers will review how to identify invasive plant species that have been prioritized using the outreach materials developed by the Network, and where appropriate, herbarium specimens, taxonomic keys, and photographs. The Crew Leader will also provide training on GPS navigation and field methods for recording data. All equipment and supplies, especially GPS units, shall be organized, prepared, and tested prior to the field season. All files needed for navigation will be loaded on to a GPS unit and on to a laptop, which will be taken to the park. SOP #4: Setting up the Electronic Field Equipment explains how to use the GPS.

At least 1 month prior to when Network crews expect to visit the field sites, the Park Contact at each park will be contacted to assure all logistical needs are addressed and on schedule. Each day, the Crew Leader shall provide a briefing regarding any safety, plant identification, and park navigation issues of concern for the day. The Crew Leader will also assign crew members to the search units for the day. Crew members will navigate to their units using the GPS unit, compass, and maps. Crews will be locating random plots while in the field following SOP #5: Field Survey Methods.

3.2 Collecting and Recording Data in the Field

Data are collected using field computers (Trimble GeoExplorer) with ArcPad and GPS units (Garmin 60/76 CSx). Instructions for using the hardware and software are provided in SOP #4: Setting up the Electronic Field Equipment. The data will also be recorded on standardized datasheets for the first few years to act as a backup for the electronic devices. A description of how to enter the data is provided in SOP #6: Data Collection and Entry. Hardcopy and electronic datasheets should be reviewed before leaving the monitoring segment to make certain they are complete. At the end of the field day, data are transferred electronically from the GPS to a laptop computer. At the end of a park-specific sampling trip, data forms are submitted to the Crew Lead and electronic data are transferred to the Network database.

3.3 Post Field Season

After the field season, a number of activities need to occur to finalize the year's sampling efforts and help ensure smooth start-up for the next field season (SOP #13: Post Field Season). Equipment is to be cleaned, inventoried, and stored. Any equipment that is found to be in need of repair or replacement will be identified to the Crew Lead. A short report about the year's sampling shall be prepared. Findings that are urgent for managers will be described in a written briefing to be sent to parks by December 1 (SOP #10: Reporting and Analyses of Data).

Data will be reviewed by the Project Lead, who has the authority to delegate this task to the Crew Leader. Once the data have been reviewed and corrected, automated processes are enacted by the Data Manager to upload the data into a master database that stores all the data for this project.

4.0 Data Management, Analysis, and Reporting

This section will focus on all aspects of managing, storing, analyzing, and reporting monitoring data according to the Network's Data Management Plan (Mohren 2007) and the reporting schedule in the Klamath Network Monitoring Plan (Sarr et al. 2007). Methodological details are located in these plans and the SOPs referenced herein. It is crucial to successful monitoring that project personnel understand all necessary data management methodologies. This includes who is responsible for implementing the methods and the timelines they are expected to follow when conducting data management.

4.1 Data Management

Data management begins with preparation for field work (SOP #2: Field Work Preparation); includes data collection and entry in the field (SOP #6: Data Collection and Entry); addresses data storage, analysis, and archiving at the end of the field season (SOP #8: Data Transfer, Storage, and Archiving); and includes data analysis and reporting (SOP #10: Data Analysis and Reporting). The data management cycle for the sampling year ends with a review of the yearly project activities. It is the responsibility of the Project Lead and Crew Leader to make sure all crew members are trained in proper data management protocols and procedures. It is also the responsibility of the Crew Lead to transfer all completed data to the Data Manager. However, at least one of the crew members will be trained in data transfer to act as a backup. Data entry will be completed using electronic and paper formats for the initial years of the project. Unless stated otherwise, data entry will be uploaded from the field computers to the desktop database and backed up on a nightly basis. Data will be transferred from the field PC to the master database at the end of the field season after all quality control and quality assurance process have been followed. It is the responsibility of the Project Lead or Crew Lead to make sure all electronic data collected during the field visit are transferred to the Data Manager, and that hardcopy datasheets are scanned and archived according to procedures detailed in SOP #8: Data Collection and Entry.

4.2 Metadata Procedures

Details on the process to develop, update, distribute, and archive metadata are provided in SOP #11: Metadata Guidelines. In general, metadata will be completed at the onset of implementing the Invasive Species Early Detection Protocol. Metadata will be created using Environmental Systems Research Institute (ESRI) tools, the NPS Metadata tools and Editor, and the NPS Database Metadata Extractor. Metadata will be to Federal Geographic Data Committee (FGDC) and NPS standards where applicable. Metadata will be created for the master database and priority species list. It is the responsibility of the Crew Lead to complete the Metadata Interview form at the end of each field season to document changes to the metadata. If changes have occurred, it is the Data Manager's responsibility to archive and update the metadata for each database.

4.3 Overview of Database Design

The invasive plant monitoring protocol requires two databases: 1) the invasive plant prioritization database, to be periodically updated as described in SOP #1: Invasive Plant Prioritization, and 2) the invasive plant location information database. Microsoft Access is the primary software environment used for these databases. The database utilizes the Natural

Resource Database Template (NRDT), developed by the NPS, and incorporates tools from the Nature Conservancy database called WIMS (Weed Information Management System) that are used to collect, view, manipulate, and report data and information.

Invasive plant prioritization database – There are separate Excel files for each park. Multiple worksheets are in each spreadsheet, with species lists, raw scores, and the final ranking (with graphs) for species in each of the three phases of invasion (SOP #1: Invasive Plant Prioritization has definitions of invasion phases). The spreadsheets are formatted so that the data feed directly into the ranking software. The software Criterium Decision Plus 3 http://www.infoharvest.com/ihroot/index.asp will be used to rerun the calculations when reprioritizations are done after the first sampling season and every 5 years thereafter. Final species lists are uploaded into the invasive plant information database described below.

The invasive plant information database – Development of a national, standardized invasive plant database is essential to the effective collection, dissemination, and consistent interpretation of invasive plant data. This is particularly true for early detection and rapid response efforts, which rely on predictable and transparent communication tools to engage an appropriate management response. At this time, an NPS national invasive plant database is still in the planning stages while the NPS Natural Resource Program Center (NRPC) transitions data systems to a Service Oriented Architecture and Extendible Markup Language (XML), web-based services development approach for data management and delivery. Therefore, the Network began to research the availability of other invasive species databases.

After examining existing invasive plant databases, we decided that we could utilize the NRDT, and then incorporate some of the tools that are available in the WIMS database. The Nature Conservancy's Weed Information Management System (WIMS) in its current state would meet 80% of the needs outlined in this protocol and provide an affordable and adaptable platform for customizing to our specific needs. This free database gives us the opportunity to use mobile mapping technologies; is very well documented with user guides, metadata, and setup instructions; incorporates the North American Weed Management Area standards; and is simple enough that it could easily be altered to meet all the needs of this project. In addition, discussion with staff at the national level have assured us that the national NPS database will have tools designed to upload data being collected using The Nature Conservancy's Weed Information Management System (WIMS). We decided to utilize the NRDT format instead of solely using WIMS to ensure the data collected as part of this protocol are stored in a format that is compatible with the database from other KLMN protocols and data management databases (e.g., image database, project database).

This protocol will use a database that integrates a suite of hardware and software elements to simplify the collection and management of invasive plant data. The central piece of the database is the relational MS Access database ("the database") that works to keep track of all invasive species' occurrences (documenting presence), assessments (monitoring), and all management treatments for invasives in a defined area. This database can be used in combination with ArcPad (the handheld version of ArcGIS) and a personal digital assistant with an attached GPS or a Windows-compatible GPS unit, like the Trimble GeoXT or Thales Mobile Mapper CE. If technical difficulties arise, data can also be collected on paper and manually entered into the database. Once a national database has been completed, we will reassess the database methods of this protocol to see if converting to the national database is necessary. Addition details about this database are provided in SOP #9: Databases.

4.4 Data Dictionary

The data dictionary for field data entry meets the standards set by the North American Weed Management Association. This data dictionary and the one for the invasive species prioritization are to be finalized at the onset of implementing the Invasive Species Protocol. It is the Crew Lead's responsibility to update the data dictionary (if needed) at the end of each field season. In addition, the Metadata Interview form, which will be submitted at the end of each field season, will be used by the Data Manager to indicate if changes have occurred to the metadata or data dictionary. The current data dictionary and relationship diagram for the main tables of the database is provided in Appendix D.

4.5 Data Entry, Verification, Validation, and Editing

Data entry will consist of transferring data from field collection devices (currently Trimble GeoXH) to a desktop computer located in a stable environment. Forms have been created to be used in conjunction with the electronic collection devices that incorporate pick list, domain values, and automated, populated fields. In addition, for the initial years of data collection, hardcopy datasheets will be completed to help with verification process described below. Details on the data entry process are described in SOP #6: Data Collection and Entry.

Data verification is the process of ensuring the data entered into a database correspond with the data recorded on the hardcopy field forms and data loggers. After collecting the field data, but prior to leaving the sample segment or site, the field crew will review all hardcopy and electronic data forms to make sure they are complete. After the end of the sampling period in a park, the Crew Lead will review the data to make sure everything has been entered properly. In addition, the Crew Lead should examine the data after collection has occurred for 1 week, to ensure field crews are following collection and data entry methods properly. At the end of the field season, a field crew member should cross-check the hardcopy field forms with the electronic data (SOP #6: Data Collection and Entry).

Data validation is the process of reviewing the finalized data to make sure the information presented is logical and accurate. Data validation requires a reviewer to have extensive knowledge of what the data mean and how they were collected. At the end of the season, the Crew Lead will compile data from all field surveys. This person should examine the data using general tools built into the database and his/her personal knowledge to ensure the data are accurate.

Once all validation and verification methods have been implemented, the databases will be transferred to the Klamath Network Data Manager, who will upload the data to the master database. While uploading the data into the database, the data will be subjected to an automated data quality process that will flag potential missing sites and invalid or improperly formatted data.

4.6 Data Certification

Data certification is a benchmark in the project information management process that indicates that: (1) the data are complete for the period of record; (2) they have undergone and passed the quality assurance checks; and (3) they are appropriately documented and in a condition for archiving, posting, and distributing. Certification does not necessarily mean that the data are completely free of errors or inconsistencies. Rather, it describes a formal and standardized process to track and minimize errors.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all data. The Crew Lead is primarily responsible for completing the Data Certification form, available on the KLMN web sites. This brief form is to be submitted with the certified data according to the timeline in SOP #6: Data Collection and Entry.

4.7 Product Distribution

It will be the Klamath Network Data Manager's responsibility to utilize the season's certified raw data, along with the materials presented in the biennial report, Analysis and Synthesis Report, data dictionary, and Metadata Interview form to populate or update the NPS I&M databases including NPSpecies, NatureBib, and the NPS Data Store. Details on distribution can be found in SOP #8: Data Transfer, Storage, and Archive. In general:

- All reports will be posted on the NPS Data Store and KLMN Internet and Intranet web pages.
- The full report will be sent to the Resource Chiefs of each park and to any park staff that are associated with the project.
- A short, one-page summary of the report will be sent to all park staff.
- One record will be created in NatureBib for each annual report, comprehensive report, and third year Analysis and Synthesis Report and linked to the corresponding species in NPSpecies.
- Metadata for each database will be created and updated based on the Metadata Interview form and data dictionary provided by the Crew Lead each year. Metadata for the project database will be posted at the NPS Data Store.
- Photographs and metadata provided for photographs will be stored in the project folder located on the Klamath Network shared drive. Images will be uploaded to the KLMN Image database (SOP #7: Photo Management).
- Three GIS shapefiles will be created documenting transects sampled, species locations, and vegetation plots. These files will be created by the Crew Lead, working with the GIS Specialist, and stored on the KLMN GIS Server.
- Upon completion of a deliverable, the Crew Lead will notify the Data Manager and Program Assistant, who will work together to update the KLMN Project Database and web sites.

4.7.1 Holding Period

To permit sufficient time for the Network to have the first priority to publish data, when the park staff or the public requests data, it will be understood that these data are not to be used for publication without contacting the Project Lead. After each 5-year survey cycle, all certified, non-sensitive data will be posted to the NPS Data Store. Note that this hold only applies to raw data and not to metadata, reports, or other products that are posted to NPS clearinghouses immediately after being received and processed.

4.7.2 Sensitive Information

Certain project information related to the specific locations of rare or threatened taxa may meet criteria for sensitive data and, as such, should not be shared outside NPS, except where a written confidentiality agreement is in place. Before preparing data in any format for sharing outside NPS, including presentations, reports, and publications, the Project Lead should refer to the guidance in SOP #8: Data Transfer, Storage, and Archive. Certain information that may convey specific locations of sensitive resources or treatments may need to be screened or redacted from public versions of products prior to release. All official Freedom of Information Act (FOIA) requests will be handled according to NPS policy. The NPS Lead will work with the Data Manager and the FOIA representative(s) of the park(s) for which the request applies.

4.8 Data Summaries and Analyses

Data summary routines that will be undertaken include: 1) maps for invasive plant distribution and infestation sizes in portions of each park sampled; 2) summary statistics and correlation analyses from plot-based sampling; and 3) changes in invasive species distribution and abundance over time in resampled units, which then may be linked to management actions, disturbances, etc. Additional analyses that will be undertaken with the data include spatial interpolation and other modeling to help predict habitats prone to invasion. Data from the vegetation monitoring protocol will also be useful for these analyses. Details on data analyses and the reporting schedule are provided in SOP #10: Reporting and Analyses of Data.

4.9 Schedule and Contents of Reports

A primary objective of this protocol is to provide monitoring information to park management on a timely basis to allow effective management responses. Therefore, a one-page briefing paper will be developed that summarizes the findings in the field immediately following the field season. This paper is not meant to convey all the efforts of the year but to act as an interest document that provides limited information and points readers to the more detailed document, if necessary.

More detailed, formal reports will be prepared in years alternating with field seasons. These biennial reports will document all findings including number of occurrences by road, trail, and powerline; by species; and management recommendations to be implemented during the alternate years. Biennial reports will also include the time spent surveying and miles covered. Maps of locations and presence/absence of species along survey routes will also be prepared for the reports.

Analysis and Synthesis reports will be prepared every sixth year (SOP #10: Reporting and Analysis of Data). The first Analysis and Synthesis Report will also include an assessment of whether the protocol is meeting objectives and any updates needed to the invasive species prioritization. The protocol will be adapted accordingly. The second Analysis and Synthesis Report will assess the invasion process using spatial modeling aimed at predicting the environments in which select invasives are most likely to invade. Appendix C provides a detailed description of the modeling methodology. The third Analysis and Synthesis report will investigate dynamics in invasive species abundance, which will be reported in terms of density, area occupied, overlap in area occupied, and persistence of infestations. Management actions will be evaluated as a covariable.

Formal reports will be prepared and distributed by May 1st of the year following monitoring. These reports will use the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting. Biennial reports will be formatted using the Natural Resource Technical Report template located at the NPS Natural Resource Publications web site (NPS 2006a).

Reports will be posted in NatureBib, KLMN Internet and Intranet web sites, and SOU's bioregional electronic archive collection. Reports will also be sent to the Technical Advisory Committee and to park staff who have invested interest in this project. Reports will also be used to update NPSpecies.

In addition to formal reports, field crews will meet with park resource staff upon completing their seasonal field work. The purpose of these meetings will be to convey the most urgent findings verbally so that park managers can schedule more immediate treatments if appropriate and feasible. GIS layers showing data collected during each year will also be provided to the parks no later then December 1st of the year of a survey.

4.10 Data Storage and Archiving Procedures

File structure, version control, and regular back-ups are carefully controlled to preserve the integrity of network datasets (KLMN Network Data Management Plan [Mohren 2007]). As described above, all data are transferred to the Network Data Manager, who places them on a Network server that is subject to regular archiving and backup processes, as described in the Network's Data Management Plan.

During the field season, field forms will be submitted to the Project Lead and stored in cabinets at the end of each sampling trip. At the end of the field season, these datasheets will be scanned into PDF documents and stored in the Invasive Species Early Detection project folder located on the Klamath Network server.

Prior to the start of a new field season, all products from the prior field season should have been transferred to the Project Lead (SOP #8: Data Transfer, Storage, and Archive). The Project Lead will work with the Data Manager to make certain that products are stored in their proper location on the KLMN server and posted to the proper distribution locations.

5.0 Personnel Requirements and Training

5.1 Roles and Responsibilities

Roles and responsibilities under this protocol are summarized in Table 3. The Klamath Network Coordinator serves as the Project Lead, with ultimate responsibility for executing the protocol. The Network will hire a botanist or plant ecologist to serves as the Crew Leader to guide field operations for invasive plant monitoring. The Network Coordinator supervises the Crew Leader. The data management aspects of the monitoring effort are the shared responsibility of the Crew Leader and the Data Manager. The Crew Leader oversees data collection; data entry; data verification and validation; and data summary, analysis, and reporting. The Network Data Manager designs and maintains the database and oversees data security, archiving, and dissemination. The person in this position, in collaboration with the Crew Leader, also develops data entry forms and other database features to assure data quality and to automate report generation. The Network Data Manager is responsible for building adequate quality assurance/quality control procedures into the database management system and for following appropriate data handling procedures.

Table 3. Roles and responsibilities for implementing the Klamath Network Vegetation Monitoring Protocol.

Role	Responsibilities	Position
Project Lead	Project oversight	Klamath Network Coordinator
	Administration and budget	
	Consultant on all phases of protocol review	
	Evaluates progress toward meeting objectives	
	Facilitates communications between NPS and parks	
	Conducts periodic research on invasion ecology	
	Analyzes and interprets monitoring results	
	Leads report preparation	
	Leads protocol revision (SOP #12: Revising the Protocol)	
Data Manager	Oversees all data management activities	Klamath Network Data Manager
	Makes certain data are posted	
	Makes certain all products and deliverables are reviewed, submitted, stored, and archived	
	Maintains and updates database application	
	Provides database and data management training as needed	
	Consultant on GPS/GIS use	
	Works with Project Lead to prepare and analyze data	
	Ensures metadata have been developed for appropriate project deliverables (e.g., databases, GIS/GPS documents, images, etc.)	
	Primary steward of Access database and GIS data and products	
GIS Specialist (Data Manager and/or Project Lead in future)	Provides spatial data analysis that may be needed (e.g., GRTS)	Klamath Network GIS Specialist
	Develops metadata for spatial data products	
	Maintains GPS units	
	Helps train crew members on GPS use	
	Prepares maps for field crews	
	Prepares maps and graphics for reports	

Table 3. Roles and responsibilities for implementing the Klamath Network Vegetation Monitoring Protocol. (continued).

Role	Responsibilities	Position
Crew Leader	Suggests changes to protocol	GS-7 Term Botanist
	Maintains research permits	
	Coordinates hiring of field crews	
	Coordinates scheduling, travel, and accommodations	
	Acquires and maintains field equipment	
	Trains field teams on vegetation sampling techniques, plant identification, and any other aspects of the protocol	
	Performs data summaries, analyses and provide text for reports	
	Maintains and manages voucher specimens	
	Maintains and archives project records	
	Certifies each season's data for quality and completeness	
	Creates metadata for products in GIS, GPS, image, and document format	
	Maintains research permits	
Field Crew	Collects, records, enters, and verifies data	Seasonal Network staff
	Provides recommendations to improve protocol operational efficiency	
Administrative contact	Arranges vehicles	Klamath Network Program Assistant
	Coordinates timesheets, purchasing, and reimbursements	
	Performs copy editing and report production	
	Manages equipment checkout	
Park Contact	Consultant on protocol implementation	Park botanist, plant ecologist, or Resource Chief
	Facilitates logistics planning and coordination	
	Helps interpret management implications of results	
	Reviews reports, data and other project deliverables	

The Project Lead is responsible for representing the Klamath Network in all issues related to this protocol. The Project Lead should be in constant communication with Crew Lead and park staff to make certain the protocol is being properly implemented. It is the responsibility of the Project Lead to be familiar with all aspects of the protocol and to provide assistance to the Network and parks when necessary.

Each park within the KLMN has designated a Park Contact for the invasive species protocol. It is the responsibility of the Project Lead to contact the Park Contact when necessary. Park Contacts will help support the Invasive Species Monitoring, when necessary, by participating in meetings, helping with logistical planning at their associated parks, and providing assistance with other miscellaneous tasks to ensure that the crew can perform the work efficiently in their park.

The field work, seasonal data management, and data entry activity to be completed under this protocol will be conducted primarily by two GS-5 level seasonal employees at the GS-5 pay scale in a single 6 month field season every other year. They will work under the direct supervision of the Crew Lead. When and where feasible, we will explore means to supplement this core staffing with park-based employees or volunteers, or assistance from the Project Lead during critical periods, but ultimately the scope and complexity of the field monitoring will be designed specifically for the capabilities of the assigned seasonal employees.

5.2 Qualifications and Training

Competent, observant, and detail-oriented observers are essential for collecting credible, high-quality invasive plant data. The Crew Leader must have strong botanical, organizational, and leadership skills to ensure the crew is well outfitted, scheduled, adequately trained, and motivated do their best work. The crew members must take initiative to read and understand the protocol elements for which they will be responsible and to ask for clarification from the Crew Lead, when questions arise. All field observers must possess sufficient botanical skill to accurately recognize the prioritized invasive plants and note other potentially important species that they encounter. Field observers must also be competent with GPS navigation, compass use, estimating plant cover, and data collection. All crew members should be well organized, function well as a team member, be comfortable in the field, and work methodically under difficult conditions. They must also be willing to work flexible schedules that may include long work days and inclement weather.

Training is essential for developing competent observers, both at the initiation of the field season and thereafter. At the start of the season, observers will review invasive plant identification using interpretive materials developed by the Network, as well as herbarium specimens, keys, and photographs. The Crew Leader will ensure that training is adequate and provide a refresher on invasive plant identification, GPS navigation, etc. at the start of the season (SOP #2: Field Work Preparation). The Crew Lead should work closely with the Data Manager to train field crews on all data collection devices. As data are recorded or uploaded, additional training will ensure that data are recorded accurately, errors identified in a timely fashion, and all data are backed up in the most efficient and secure way in each park.

5.3 Training Volunteers

Youth Conservation Corps volunteers are trained to identify the prioritized invasives and to do the monitoring by resource management staff at Lava Beds. This monitoring supplements the Network monitoring program. It is also possible that parks or the I&M Program will obtain occasional supplementary funding to support Student Conservation Association interns to assist with field efforts. For volunteers to function as auxiliary observers for this protocol, they will be trained on or demonstrate competency in field observation, data collection, and data management comparable to paid field crew members.

5.4 Safety

The field crew will be working in some remote areas; it is therefore essential that everyone, to the extent possible, be prepared for emergency situations. The Klamath Network has developed job hazard assessment documents specific to each park, to which crew members will strictly adhere while working at the parks (Appendix E). The safety protocol addresses known hazards (e.g., poison oak, rocky terrain, etc.), wildlife issues, communications, first aid, and an emergency response plan. Prior to going into the field, as part of observer training (SOP #3: Observer Training), the Crew Lead shall review safety procedures and job hazard analyses (Appendix E) with all field crew personnel.

6.0 Operational Requirements

6.1 Annual Workload and Implementation Schedule

The annual schedule for implementing the protocol is shown in Table 4.

Table 4. Annual schedule of major tasks and events for the Klamath Network vegetation monitoring protocol.

Month	Administration	Field	Data Management/Reporting
January	Briefings and data delivery to parks complete Begin recruiting and hiring seasonal personnel	Hire seasonal staff and schedule field visits, reserve campgrounds, and vehicles	Finish data analysis from previous year. Prepare Biennial Report and/or Analysis and Synthesis report from previous season
February	Administer and modify existing agreements, if necessary		Prepare biennial or analysis and synthesis report
March	Final protocol modifications (if any)	Inventory field equipment and resupply where needed	Prepare biennial or analysis and synthesis report
April		Prepare field and GPS/electronic equipment. Train field crew	Finish biennial or analysis and synthesis report
May		Begin field work	Turn in biennial report. Finish analysis and synthesis report
June		Field work	Turn in analysis and synthesis report
July			
August	Prepare budget for new fiscal year		
September	Close out of fiscal year	Finish field work. Field season closeout and briefing report	Metadata production
October	Network Annual Report and Workplan drafted	Data verification	Data certification and archival
November			Data analysis
December			

Monitoring will require one two-person crew each year. Approximately 6 months or 240 person-days per crew member will be required annually to complete training, field data collection, and seasonal data management activities for this protocol. This level of effort may be supplemented by splitting the crew and adding volunteers during “crunch” times when vegetation in multiple parks is ready for monitoring (typically late May/early June in WHIS, LAVO, and REDW and late July/August in LAVO and CRLA). The number of person-days may change slightly depending on the abundance of invasive species, logistics, weather, and other factors. Positions will be announced during the winter prior to a field season. Crews will be hired during early spring to enable training by mid-spring and sampling by late spring (Figure 10).

6.2 Facility and Equipment Needs

Equipment and facility requirements for this protocol are modest. The crew will typically require housing or camping facilities in each park for 1 to 6 weeks. The Project Lead or Crew Lead will need to contact the Park Contact the winter before field work begins so arrangements can be made. The invasive plant monitoring requires a 4-wheel drive vehicle, computers, GPS units, hand-held computers, a laser rangefinder, a densiometer, taxonomic guides, tape measures, hand lenses, identification material, and a digital camera. For safety purposes, crews will also carry radios and/or cellphones to communicate, if necessary, with park staff in the event of emergency (SOP #2: Field Work Preparations). During the off-season, equipment will be kept and maintained at the Klamath Network office.

6.3 Startup Costs and Budget Considerations

Startup costs include the purchase of equipment and supplies, as well as maintenance and/or replacement of equipment shared among multiple projects (e.g., GPS units, cameras, vehicles) (Table 5). All equipment that needs to be purchased has been acquired prior to the implementation of this protocol. Additional monies ($4,000) are budgeted each year of data collection to cover equipment repair or replacement for this specific protocol.

This protocol will have an alternating budget appropriation starting out at just over $83,000 per year during field sampling (odd years). Of this, nearly $32,000 is base funding for core staff. During even years, just over $24,000 will be spent, all from base funding. This staggered allocation supports an intensive 6 month field season, whereby crews visit all the parks in the Network, while the budget also provides additional monies for analysis and reporting in alternate years. During the alternate years, the Project Lead and Crew Lead will conduct the analysis and reporting and prepare biennial reports. During every sixth year, the effort spent on reporting will increase. The Network expects to work with academic or USGS researchers to help with the spatial modeling and trend analyses. The decision to only conduct field monitoring every other year was made because alternate year monies will support cave monitoring efforts. We anticipate that control efforts for invasive species would be modified during each year following the field work to allow rapid application of monitoring results on the ground. We expect that the budget allocation will increase modestly due to inflation of general costs and cost of living increases for salaried staff. These increases will be addressed in part by scheduled cost of living increases for the KLMN monitoring budget based upon agency staff employed.

Table 5. Estimated startup costs and annual budget for KLMN invasive plant monitoring for A. 2011, B. 2012, and C. 2013, representing two field sampling years and one reporting year.

A. 2011

	Expense Item	Person-Months	Salary	Benefits	Total
Personnel	Network Program Manager	1.5	$6,416.00	$2,406.00	$13,233.00
	Network Data Manager	1.0	$5,200.00	$1,950.00	$7,150.00
	Crew Leader, GS-7	2.0	$4,172.00		$11,431.28
Subtotal (Base-funded Office Staff)					$31,814.28
	Field Crew, GS-5	12.0	$2,704.00		$35,043.84
Other	Equipment/Supplies				$4,000.00
	Travel				$4,000.00
	Vehicles				$9,000.00
Subtotal (Fieldwork Only)					$52,163.84
	Total				$83,558.12

B. 2012

	Expense Item	Person-Months	Salary	Benefits	Total
Personnel	Network Program Manager	1.0	$6,416.00	$2,406.00	$8,822.00
	Network Data Manager	1.0	$5,200.00	$1,950.00	$7,150.00
	Crew Leader, GS-7	1.5	$3,973.15		$8,164.82
Subtotal (Base-funded Office Staff)					$24,136.82
	Total				$24,136.82

C. 2013

	Expense Item	Person-Months	Salary	Benefits	Total
Personnel	Network Program Manager	1.5	$6,416.00	$2,406.00	$13,233.00
	Network Data Manager	1.0	$5,200.00	$1,950.00	$7,150.00
	Crew Leader, GS-7	2.0	$3,973.15		$10,886.43
Subtotal (Base-funded Office Staff)					$31,269.43
	Field Crew, GS-5	12.0	$2,626.00		$34,032.96
Other	Equipment Supplies				$4,000.00
	Travel				$4,300.00
	Vehicles				$9,500.00
Subtotal (Fieldwork Only)					$51,832.96
	Total				$83,102.39

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